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Economic Use of Forages in Livestock Production on Corn Belt Farms

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CONTENTS

	Page
Introduction	1
Forage-grain substitution relationships	2
Relationship of crop enterprises and forage utilization	2
Livestock substitution relationships	4
Cost relationships	10
Forage-grain production in relation to utilization	12
Capital and labor requirements of feed-utilization systems	16
Labor requirements	18
Returns from labor	19
Capital requirements	22
Returns on investment in relation to feeding system	26
Relationship of feed-utilization system to risk and uncertainty	32
Feed combinations and market uncertainty	32
Adjustments to changing price relationships	38
Summary	41
Rotation relationships	42
Feed substitution in livestock rations	42
Capital and labor requirements of feed-utilization systems	43
Risk and uncertainty	44
Literature cited	44

INTRODUCTION

Well-managed, high-yielding grasses and legumes have a well-defined place in the crop rotation on Corn Belt farms. They retard erosion, improve soil structure and tilth, increase and sustain yields of other crops in the rotation, and provide more feed for livestock. Both conservation and production benefits from them are important. The growing need for more livestock products and rising costs now emphasize the importance of good pastures and meadows as sources of feed.

Farmers in the Corn Belt generally recognize the soil-building characteristics of grasses and legumes. Many, however, do not use optimum acreage of these crops to provide cheap feed and to improve their soils because they do not realize the full potentialities of their

hay and pasture. One reason is that they are not sufficiently familiar with the results that can be obtained both from using methods of production and harvesting which improve yields and lower costs and from feeding rations with higher proportions of good-quality forage. Some also hesitate to grow and feed more forages because they lack the additional capital or they are unwilling to take the greater risks that would be involved in different systems of farming.

The purpose of this bulletin is to analyze some of the relationships that farmers should consider in deciding how much forage to produce and how to use it. Significant aspects of this problem are (*a*) the rate at which forages substitute for other feeds and (*b*) the labor, capital, and risk or uncertainty that are associated with different systems of livestock feeding. Substitution relationships in both crop rotation and livestock ration are involved. Capital and labor requirements of different systems of feeding are also important because they are costs and because many farmers have limited quantities of those resources.

For the farmer who has limited capital, the choice of a method of using his forage crops may be a livestock system that will provide a relatively high rate of return for a small investment of capital. Likewise, a farmer who is not in position to stand great risks may prefer a livestock system that promises a steady income from year to year, even though it may not provide as high an average return during several years as some other system. But a farmer who has ample capital is in position to choose the method of utilizing forage crops that is likely to give him the highest average returns during a period of years, irrespective of the likelihood of large losses in some years.

Data for this analysis of feed substitution relationships, capital and labor requirements, and degree of risk associated with different systems of feeding dairy cows, beef cattle, feeder lambs, and hogs were obtained from available reports and unpublished information on livestock-feeding experiments, previous farm-management studies, and price statistics.

FORAGE-GRAIN SUBSTITUTION RELATIONSHIPS

Relationship of Crop Enterprises and Forage Utilization

Forage crops may bear either of two relationships with grain crops. They are complementary if an increased acreage of forage causes total production of grain to increase from a given area of land. They are competitive if a greater acreage and production of forage is possible only as production of grain is sacrificed on a given area of land. These two relationships are illustrated in the data of table 1, which are based on rotation experiments. As the last three columns show, some combinations of hay and grain produce more pounds of grain than grain crops alone on 100 acres of the two soil types included. But a further extension of the acreage of forage results in a decrease in total production of grain. The Ohio data show that not only does forage become competitive with grain but each additional increase in the output of forage results in a greater decrease in the total production of grain.

Profitable production of forage does not depend on the way they are utilized if the grasses and legumes are complementary to grain. It pays to extend production of forage so long as an increase in acreage of forage is accompanied by an increase in total production of grain, even though no direct return is realized from feeding the forage. Forages can be turned under as green manure crops. When this is done income is greater than when a smaller acreage of grasses and legumes is produced. However, income can generally be increased even further if forages are utilized as feed. Farmers then have two sources of income from forages: That forthcoming from the nitrogen, organic matter, or erosion control which may add to total production of other crops; and that forthcoming from the sale of products from roughage-consuming livestock.

TABLE 1.—*Complementary and competitive relationships in forage production for various crop rotations on 2 soil types*

WOOSTER AND CANFIELD SILT LOAMS, WOOSTER, OHIO, 1937–43[1]

Rotation [2]	Use of 100 acres of land		Total production		Amount of grain sacrificed for each pound of hay added over previous rotation
	Grain	Hay	Grain	Hay	
	Acres	*Acres*	*Pounds*	*Pounds*	*Pounds*
C	100	0	217, 840		
C-C-C-W-A	80	20	229, 776	128, 800	([3])
C-W-A	67	33	215, 480	203, 200	0. 19
C-C-W-A-A	60	40	190, 672	316, 000	. 22
C-W-A-A	50	50	165, 928	363, 000	. 53

CLARION-WEBSTER SILT LOAM, AMES, IOWA, 1945–48[4]

Rotation [2]	Grain (acres)	Hay (acres)	Grain (pounds)	Hay (pounds)	Grain sacrificed per pound of hay (pounds)
C	100	0	180, 320		
C-C-O-Cl	75	25	217, 360	85, 000	([3])
C-O-Cl	67	33	182, 333	132, 660	0. 71

[1] See Yoder, R. E. (*10*).
[2] C=corn, O=oats, W=wheat, Cl=clover, A=alfalfa.
[3] Complementary.
[4] From unpublished data, Dept. of Agronomy, Iowa Agr. Expt. Sta., Ames, Iowa, 1915–48.

If capital is so limited that investment in livestock is impossible, the only alternative for a farmer may be to use the complementary forage as a green-manure crop.[1] A farmer who is less limited in capital has a more complex problem of utilizing forages. He may lack capital to invest in enough livestock to consume all forage produced complementary with grain. He will be concerned with the combination of livestock and feed-utilization systems that will bring the largest income or will involve the smallest risk per dollar invested. This may not mean complete utilization of the complementary forage.

Problems of production and utilization are more complex for a farmer who has ample capital. A farmer whose ability to utilize

[1] Individual farmers in some areas may find it possible to lease pasture land to neighbors or to sell hay; often no such opportunity exists.

forage in livestock production is not limited by availability of capital must consider how much to expand production of forage into the competitive areas as well as the problem of how to utilize the forage. Here substitution relationships become significant in deciding upon both the best ration for a particular type of livestock and the rotation that will allow a maximum value of livestock products from a given quantity of land and other resources.

Although they may be extremely limited as to capital, many farmers must operate in the competitive area. This may be true for some because under their soil situations the grain-forage relationship is competitive throughout all combinations. For many it may be true because they remain on a particular farm only a short time. In a single year the relationship between forage and grain is competitive and, therefore, the complementary aspects of forage-grain combinations have no significance unless the individual remains on the farm long enough for the indirect benefits of the rotation to be realized. Further discussion of optimum combinations of forage and grain from the viewpoint of both production and utilization follows an examination of the rates at which forage substitutes for grain in livestock-feeding rations.

Livestock Substitution Relationships

A given quantity of a livestock product (100 pounds of milk, pork, or beef) can be produced with many combinations of grains and forages. Beef or milk can be produced with forages alone and pork or poultry products can be produced with grains alone. However, grain and forages can be substituted for each other so that 100 pounds of livestock product can be produced with many combinations of the two feeds. The lowest-cost combination among these combinations depends upon (1) the rate at which forage substitutes for grain in producing a given quantity of livestock product and (2) the price or cost of forage relative to that of grain.

For example, suppose that 100 pounds of milk can be produced with 40 pounds of corn and 94 pounds of alfalfa hay. Suppose further that the same quantity of milk can be produced with only 37 pounds of corn if 100 pounds of hay are included in the ration. In these two examples the addition of 6 pounds of forage reduces the grain requirement by 3 pounds. That is, the additional 6 pounds of hay are equivalent to 3 pounds of grain in producing milk. If hay is worth a cent a pound ($20 per ton) and corn is worth 2.5 cents a pound ($1.40 per bushel), the additional 6 pounds of hay fed would be worth only 6 cents, whereas the 3 pounds of corn saved would be worth 7.5 cents. Obviously it would pay to make the substitution.

Will it pay to substitute still more forage for grain? The answer depends on the nature of the substitution relationship—whether forage substitutes for grain at a *constant* or at a *diminishing* rate. If the rate is constant, each additional 6 pounds of hay will replace another 3 pounds of grain. Obviously, with hay at a cent a pound and grain at 2.5 cents a pound it would be profitable to replace all of the grain in the ration with forage. If the price of hay rose in relation to that of grain, so that 6 pounds of hay were more expensive than 3 pounds of grain, it would not pay to include any hay in the dairy ration.

Thus if forage substitutes for grain at a constant rate it pays farmers to feed either all grain or all forage, depending on the price of each. But a constant rate of substitution is inconsistent with the feeding practices of livestock farmers. Farmers generally feed a combination of grain and forage to beef cows, feeder cattle, dairy cows, and sheep. On many farms hogs also are fed forage in some form. Furthermore, studies of animal nutrition indicate that grain fed in small quantities to livestock consuming rations made up largely of forage stimulates production more than when the ration includes a smaller proportion of forage. Finally, the substitution of forage for grain is limited by the capacity of an animal's stomach. We may therefore expect that a *diminishing* rather than a *constant* rate of substitution exists between forage and grain in livestock feeding.

If forage substitutes for grain at a diminishing rate, some combination of forage and grain is usually more profitable than either extreme of all grain or all forage in the ration. Returning to the example of forage and grain requirements for production of 100 pounds of milk, let us suppose the amount of forage in the ration is increased from 100 to 106 pounds. The previous increase of 6 pounds in the amount of forage fed resulted in a saving of 3 pounds of grain. But if forage substitutes for grain at a diminishing rate somewhat less than a 3-pound reduction in grain requirements would be expected as a result of this last 6-pound increase in forage. In substituting more forage eventually a point would be reached at which the value of the grain saved would be no greater than the value of the forage added. This is the forage-grain combination which minimizes the feed cost of producing 100 pounds of milk.

Derivation of feed-substitution rates is a difficult and complex problem. Rates of substitution may vary with (1) the type and quality of grain and forages, (2) the production ability of the livestock, and (3) the general management conditions under which livestock are produced. Thus a multitude of situations exist for which substitution rates might be derived. After reviewing a wide range of experimental data, those from several experiments were analyzed to derive estimates of forage-grain replacement rates. These estimates of substitution rates between forage and grain in feeding milk cows, feeder cattle, hogs, and sheep under specified conditions are discussed in the following sections.

FORAGE-GRAIN SUBSTITUTION RELATIONSHIPS IN MILK PRODUCTION

Estimates of the various combinations of grain and forage that will produce 8,500 pounds of 4-percent fat-corrected milk per cow are shown in table 2. They are based on part of an experiment by the United States Department of Agriculture in cooperation with 10 State agricultural experiment stations, which included several hundred cows of several breeds and involved many kinds and qualities of feed (*8*). Data for 30 cows of the heavy breeds (Holsteins and Brown Swiss) in the series II experiments (grain ration varied with free choice of hay) that receive comparable feeds (legume hay, corn silage, and grain) with an expected production capacity of 300 to 400 pounds of butterfat (when fed the standard Haecker ration) were

used in making the estimates in table 2.[2] It is likely that the quantity of feed required to produce 8,500 pounds of milk would differ for cows of different producing ability fed similar kinds and qualities of feeds and for cows of a given production capacity fed different kinds and qualities of grain and forage.

Table 2 shows, first, that a wide range of combinations of grain and forage will give the same production of milk. With 5,000 pounds of forage and 6,154 pounds of grain, 8,500 pounds of milk were produced; the same amount was obtained from 11,000 pounds of hay and only 2,281 pounds of grain. It is likely that combinations beyond each of these extremes are also possible, but this experiment did not include cows producing outside this range of feed combinations.

A second relationship apparent from the data in table 2 is that forage substitutes for grain at a *diminishing* rate. Each succeeding increase in the quantity of forage fed reduces the quantity of grain required by something less than the preceding increase in forage. For example, when 5,500 pounds of forage are fed, 5,459 pounds of grain are needed to produce 8,500 pounds of milk per cow, whereas when the quantity of forage fed is increased to 6,000 pounds, only 4,892 pounds of grain are needed—a reduction of 567 pounds of grain. If the quantity of forage is increased by another 500 pounds (to 6,500 pounds), an even smaller quantity of grain (4,423 pounds) is needed to yield 8,500 pounds of milk, and the quantity of grain saved (469 pounds) is smaller than that resulting from the previous 500-pound increase in forage. Each additional 500-pound increase in the quantity of forage results in progressively smaller replacements of grain, until finally, as the quantity of forage is increased from 10,500 pounds to 11,000 pounds, the amount of grain replaced is only 138 pounds. The average quantity of grain saved per added pound of forage for each 500-pound increment in forage in the ration is shown in column 3 of table 2. This column shows that the rate at which forage substitutes for grain in the dairy ration declines from an average of 1.39 pounds of grain replaced per pound of hay added when hay is increased from 5,000 to 5,500 pounds to only 0.28 pound of grain saved per pound of hay added when the quantity of forage is increased from 10,500 to 11,000 pounds.

FORAGE-GRAIN SUBSTITUTION IN PORK PRODUCTION

A study by the United States Department of Agriculture (*3*) provided the data for the estimates of feed-substitution rates in produc-

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[2] The Jensen-Woodward study was directly related to levels of total feed for dairy cows and only indirectly to combinations of grain and forage in the ration. Higher levels of total feed were possible, however, only as levels of grain feeding were increased and the cow reduced her consumption of forage. Thus the resulting data included an element of feed substitution as well as the relationship between total feed fed and the production of milk. Within the range on the "production surface" used in the present analysis, considerable variation appeared in the combinations of grain and hay in the ration. But we cannot be certain that mingling of the two relationships (factor-factor and factor-product) has been entirely eliminated in the present analysis. Additional experiments are needed wherein an attempt is made to isolate feed-combination relationships for certain outputs per cow separately from the total feed-input milk-output relationships.

TABLE 2.—*Forage and grain feed combinations and substitution rates in producing 8,500 pounds of 4-percent fat-corrected milk per cow* [1]

Feed combinations for producing 8,500 pounds of milk per cow [2]		Average quantity of grain replaced per pound of forage added [3] (pounds)	Average quantity of forage required to replace a pound of grain (pounds)	Forage as percentage of total feed (percent)
Hay	Grain (pounds)			
Pounds:				
5,000	6, 154			44. 8
		1. 39	0. 72	
5,500	5, 459			50. 2
		1. 13	. 88	
6,000	4, 892			55. 1
		. 94	1. 06	
6,500	4, 423			59. 5
		. 79	1. 27	
7,000	4, 029			63. 5
		. 67	1. 49	
7,500	3, 694			67. 0
		. 58	1. 72	
8,000	3, 406			70. 1
		. 50	2. 00	
8,500	3, 156			72. 9
		. 44	2. 27	
9,000	2, 937			75. 4
		. 39	2. 56	
9,500	2, 744			77. 6
		. 34	2. 94	
10,000	2, 572			79. 5
		. 31	3. 23	
10,500	2, 419			81. 3
		. 28	3. 57	
11,000	2, 281			82. 8

[1] Based on following regression equation: $X_2=\left(\frac{8500}{3.56X_1{}^{.5035}}\right)^{2.5}$ where X_2 refers to pounds of grain and X_1 refers to pounds of forage per cow.

For further explanation of the derivation of substitution rates and for estimates of marginal rates of substitution at specific combinations of forage and grain, see HEADY, EARL O., and OLSON, RUSSELL O. (*5*).

[2] Total feed requirements in terms of TDN are higher for combinations that consist of nearly all grain or nearly all forage than for combinations in between because the TDN conversion factor for each feed assumes constant rates of substitution, whereas the data used in this analysis indicate a diminishing rate of substitution.

[3] Derived by dividing the change in pounds of grain by the corresponding change in pounds of hay as the forage-grain composition of the ration is varied. If the variations in the ration were small, these figures would be essentially the marginal rates of substitution at each combination. Where, as in this table, changes in the ration are large, the substitution rates derived in this manner are averages of the marginal substitution rates between two consecutive combinations. As small variations in feed rations are not ordinarily practical, the average marginal rates shown are refined enough for ascertaining the optimum forage-grain combination.

tion of pork shown in table 3. In this experiment hogs were fed varying combinations of ground legume hay and No. 2 yellow corn. Columns 1 and 2 show that 100 pounds of pork can be produced with a rather wide range of forage-grain combinations. As in the case of milk production, each additional increase in forage fed replaces a

smaller quantity of grain than does the preceding increase in forage. In producing 100 pounds of pork, the first 5 pounds of forage reduce the grain required from 327.5 to 325.1 pounds—a saving of 2.4 pounds of grain. When the amount of forage is increased from 45 to 50 pounds, the amount of grain saved is only 0.6 pound. Note that in column 3 the average amount of grain replaced by each additional pound of forage is 0.48 pound when the first 5 pounds of forage are added. This declines to only 0.12 pound of grain saved per pound of hay added when the amount of forage is increased from 45 to 50 pounds.

TABLE 3.—*Forage and grain feed combinations and substitution rates in increasing the weight of a hog from 60 to 225 pounds*[1]

Feed combinations per 100 pounds of gain in weight		Average quantity of grain replaced per pound of forage added (pounds)	Average quantity of forage required to replace a pound of grain (pounds)	Forage as percentage of total feed (percent)
Hay	Grain (pounds)			
Pounds:				
0	327.5			0.0
		0.48	2.08	
5	325.1			1.5
		.46	2.17	
10	322.8			3.0
		.40	2.50	
15	320.8			4.5
		.36	2.78	
20	319.0			5.9
		.32	3.12	
25	317.4			7.3
		.28	3.57	
30	316.0			8.7
		.24	4.17	
35	314.8			10.0
		.20	5.00	
40	313.8			11.3
		.14	7.15	
45	313.1			12.6
		.12	8.33	
50	312.5			13.8

[1] Based on the following regression equation: $X_2=327.5-0.5113X_1+0.00423X_1^2$, where X_2 refers to pounds of grain and X_1 refers to pounds of forage per 100 pounds of gain in weight.

FORAGE-GRAIN SUBSTITUTION RATES IN BEEF PRODUCTION

Production of beef is represented by many cattle-feeding systems. Production systems vary all the way from a beef herd which utilizes only forage to dry-lot feeding operations which include three times as much grain as forage. Also, a great deal of variation exists in grades of cattle fed. It is not possible here to consider the feed-substitution relationships for all of these situations. The forage-grain substitution rates given in table 4 are based on an Iowa pasture experiment which involved choice yearling feeder steers (7). The experiment was repeated in each of 5 years and included four production systems, each of which involved different combinations of forage and

grain. Grain was in the form of corn. Forage consumed while in dry lot was brome grass-alfalfa hay. Forage consumed as pasture was also a brome grass-alfalfa mixture. In deriving the substitution relationships, forage consumed as pasture was converted to its hay equivalent. Table 4 shows that a rather wide range of forage-grain combinations will produce 100 pounds of choice beef. As in production of milk and pork, less and less grain is saved as more and more forage is added to the ration.

Table 4.—*Forage and grain feed combinations and substitution rates in production of 100 pounds of gain on choice yearling feeder steers* [1]

Feed combinations for producing 100 pounds of gain in weight		Average quantity of grain replaced per pound of forage added (pounds)	Average quantity of forage required to replace a pound of grain (pounds)	Forage as percentage of total feed (percent)
Forage	Grain (pounds)			
Pounds:				
400	953. 4			29. 6
		0. 353	2. 83	
600	882. 7			40. 5
		. 326	3. 07	
800	817. 5			49. 5
		. 298	3. 36	
1,000	757. 9			56. 9
		. 271	3. 69	
1,200	703. 9			63. 0
		. 249	4. 02	
1,400	654. 0			68. 2
		. 211	4. 74	
1,600	611. 8			72. 3
		. 189	5. 29	
1,800	574. 0			75. 8
		. 166	6. 02	
2,000	541. 8			78. 7
		. 133	7. 52	
2,200	515. 1			81. 0
		. 111	9. 01	
2,400	493. 8			82. 9
		. 079	12. 50	
2,600	478. 0			84. 5
		. 056	17. 86	
2,800	467. 8			85. 7
		. 024	41. 07	
3,000	463. 0			86. 6

[1] Based on following regression equation: $X_2=1111.15-0.4219X_1+0.0000686X_1^2$, where X_1 refers to pounds of forage and X_2 to pounds of grain per 100 pounds of gain. The average gain in weight per steer was 350 pounds; the gain was less for steers on the high-grain rations and more for those on the high-forage rations. Feed requirements were converted to per 100 pounds of gain as experimental data are customarily expressed in that form.

FEED-SUBSTITUTION RATES IN LAMB FEEDING

Forage-grain substitution rates for fattening lambs shown in table 5 are based on an experiment at the Iowa Agricultural Experiment Station which involved lambs fed six combinations of chopped alfalfa hay and corn (*2*). The rate at which hay substitutes for grain in

lamb feeding falls somewhere between that for hogs and dairy cattle or beef fattening. Twenty-five pounds of choice or prime gain on feeder lambs can be produced with 40 pounds of hay and 130.9 pounds of grain. A 10-pound increase in forage reduces the grain requirement for producing 25 pounds of gain to only 125.1 pounds; thus an average of 0.58 pound of grain is saved per pound of hay added at this level. At the other extreme, an increase from 160 to 170 pounds of forage per lamb results in a decrease from 92.5 to 91.6 pounds of grain required to put on 25 pounds of prime or choice gain—a replacement rate of only 0.09 pound of grain saved per pound of forage added.

Table 5.—*Forage and grain feed combinations and substitution rates in producing 25 pounds of gain on feeder lambs* [1]

Feed combinations for producing 25 pounds of gain in weight		Average quantity of grain replaced per pound of forage added (pounds)	Average quantity of forage required to replace a pound of grain (pounds)	Forage as percentage of total feed (percent)
Forage	Grain (pounds)			
Pounds:				
40	130.9			23.4
		0.58	1.72	
50	125.1			28.6
		.50	2.00	
60	120.1			33.3
		.44	2.27	
70	115.7			37.7
		.39	2.56	
80	111.8			41.7
		.35	2.86	
90	108.3			45.4
		.32	3.12	
100	105.1			48.8
		.28	3.57	
110	102.3			51.8
		.26	3.85	
120	99.7			54.6
		.23	4.35	
130	97.4			57.2
		.20	5.00	
140	95.4			59.5
		.16	6.25	
150	93.8			61.5
		.13	7.69	
160	92.5			63.4
		.09	11.11	
170	91.6			64.7

[1] Based on following regression equation:

$$X_2=\frac{2.3118-0.0037X_1-\sqrt{(2.3118-0.0037X_1)^2+0.021175X_1-0.000031X_1^2-5.4267}}{0.014792},$$

where X_1 refers to pounds of forage and X_2 refers to pounds of grain per 25 pounds of gain.

Cost Relationships

For a farmer who buys both grain and forage in the market, feed subsitution rates and market prices of the feeds determine the least-cost feed combination for any particular level of production per

animal.[3] With grain (corn) at 2 cents a pound ($1.12 per bushel) and forage (hay) at a cent a pound ($20 per ton) and with the substitution rates shown in table 2, the least-cost feed combination for producing 8,500 pounds of milk is one that includes 8,000 to 8,500 pounds of forage and 3,406 to 3,156 pounds of grain. The rate of substitution (1 pound of grain for each 2 pounds of forage) is just equal to the inverse of their price ratios (grain at 2 cents a pound to forage at 1 cent per pound). At this combination, the value of the grain saved is just equal to the value of the forage added. That is, each pound of hay added is equal in value to the 0.5 pound of grain saved. The total feed cost of producing 8,500 pounds of milk with this feed combination is $148.12. Any other feed combination would cost more.

In producing pork a similar price relationship (grain at 2 cents a pound and hay at 1 cent a pound) means that it is not profitable to feed any forage because, as shown in table 3, each of the first 5 pounds of hay fed saves only 0.48 pound of grain. That is, it takes 5 cents worth of hay to save 4.8 cents worth of grain. If, however, the price of hay declines in relation to that of grain it may be profitable to feed considerable quantities of forage. For example, with corn at 2.25 cents a pound ($1.26 a bushel) and hay at 75 cents a pound ($15 a ton), a feed combination that contains 20 pounds of forage and 319 pounds of grain will produce 100 pounds of pork at least cost. At this level of forage feeding, 1 pound of hay replaces 0.36 pound of grain; or 75 cents worth of hay saves 81 cents worth of grain. But by adding another 5 pounds of forage only 72 cents worth of grain (0.32 pound) would be saved for each 75 cents worth of hay added.

According to table 4, it does not pay to feed large quantities of forage in producing choice beef unless forage is cheap as compared to grain. With grain at 2.25 cents a pound ($1.26 a bushel) and hay at 75 cents a pound ($15 a ton) the least-cost feed combination in producing 100 pounds of choice beef on yearling steers would be the one that includes 600 pounds of forage and 882.7 pounds of grain.

The forage-grain combination that minimizes the feed cost by putting 25 pounds of choice or prime finish on feeder lambs, when grain costs 2.25 cents a pound and forage costs 75 cents a pound, is the one that contains 90 pounds of forage and 108.3 pounds of grain. It would pay to feed considerable quantities of hay, even if prices of grain were low in relation to prices of hay. With corn at 2 cents a pound and hay at a cent a pound, it would be profitable to feed 60 pounds of forage to 120.1 pounds of grain.

Many farmers produce both the grain and forage they feed. Others produce forage on their own farms and buy grain. However, the

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[3] Feed substitution rates and hence least-cost feed combinations vary with levels of output per animal. Consequently the highest profit per animal is accomplished by (*a*) obtaining the lowest cost (feed and other resources) combination for each level of production and (*b*) extending the level of production so far as the value of the additional product is greater than the cost of the additional feed and other resources used to produce it. Thus the most profitable level of production per animal depends on the rate at which resources are transformed into a particular livestock product (for example, the number of pounds of feed required to produce 100 pounds of milk as production per cow is extended to higher levels) and the price of the product relative to the price of feed and other factors used in its production.

same basic principles apply regardless of the source of feed. For example, if it costs the farmer 5 cents to produce a pound of hay ($10 a ton) and 1.5 cents to produce a pound of corn (84 cents a bushel) the cost of 3 pounds of hay is equal to the cost of producing a pound of grain. The least-cost feed combination is then the one at which 3 pounds of hay just replace 1 pound of grain. Table 2 shows that in producing 8,500 pounds of milk at a combination that includes about 10,000 pounds of hay and 2,572 pounds of grain, about 3 pounds (2.94) of hay replace 1 pound of grain. The cost of this feed combination is $88.58. No other forage-grain combination will produce 8,500 pounds of milk as cheaply.

The same principles apply when labor and other costs are included in the calculations. It is then the total cost of feeding grain or hay which establishes the feed-cost relationships. The cost of feeding a pound of each feed in this case includes the price of the feed, plus a charge for other factors.

Forage-Grain Production in Relation to Utilization

Substitution relationships in feeding are also important in defining the maximum amount of livestock product that can be produced from a given area of land. It was pointed out earlier that even though none of the forage is utilized for feed, it is profitable to grow enough forage so that the total output of grain is as high as possible. So that it will pay to grow still more forage, the forage grown must be utilized—its value as feed must offset the value of the production of grain sacrificed. To maximize the output of livestock product obtained from a given area, the rate at which forage substitutes for grain in the crop rotation must be related to the rate at which the two crops substitute for each other in the livestock ration.

If we assume, for example, that forage substitutes for grain in the crop rotation at the rate of 2 pounds of forage for 1 pound of grain—that is, 1 pound of grain is sacrificed for each 2-pound increase in forage—then the dairy ration which allows the maximum production of milk from a given area will include 8,500 pounds of hay and 3,156 pounds of grain, on the basis of the feed requirements shown in table 2. At this combination the amount of milk that can be produced with each pound of hay added is the same as the amount that could have been produced with the 2 pounds of grain given up. With the rotation substitution rates remaining the same and with a change in the ration to include 9,000 pounds of hay and 2,937 pounds of grain, an average of 2.27 pounds of hay would be needed to replace a pound of grain in producing 8,500 pounds of milk. Yet, as the rotation was shifted to include more forage, only 2 pounds of hay could be obtained for each pound of grain sacrificed.

This example is useful only in explaining the interrelationship of substitution rates for crop rotations and for livestock rations. The response in yields of grain to increases in the proportion of forage in the rotation differs for different soil situations. On some soils (table 1) the crops may be complementary over a range; on other soils forage and grain may be competitive at all combinations. But for any type of soils, it appears likely that when acreage of forage is low an increase in forage acreage is more effective in improving yields of

TABLE 6.—*Forage and grain production combinations and substitution rates, Marshall silt-loam soils* [1]

Production combinations per acre		Average quantity of grain replaced per pound of forage added (pounds)	Proportion of total feed production that is forage (percent)
Forage	Grain (pounds)		
Pounds:			
0	1,250		0.0
		−2.20	
200	1,690		10.6
		−1.78	
400	2,045		16.4
		−1.34	
600	2,313		20.6
		−.92	
800	2,496		24.3
		−.48	
1,000	2,592		27.8
		−.55	
1,200	2,603		31.6
		.37	
1,400	2,528		35.6
		.80	
1,600	2,367		40.3
		1.25	
1,800	2,119		45.9
		1.66	
2,000	1,786		52.8
		2.09	
2,200	1,367		61.7
		2.52	
2,400	862		73.6

[1] Based on data from Seventh Annual Report (7). Forage and grain combinations are derived from the regression equation $X_2 = 1249.8 + 2.4169X_1 - 0.00107428X_1^2$, where X_2 refers to pounds of grain and X_1 refers to pounds of forage per acre.

grain than a similar increase when the proportion of forage in the rotation is already high; that is, forage substitutes for grain at an increasing rate.

Forage-grain substitution relationship for rotations on Marshall silt-loam soil are shown in table 6. These substitution rates were estimated on the basis of rotation experiments on the Page County, Iowa, experimental farm (7).[4] Columns 1 and 2 show the quantities of grain and forage produced as various proportions of an acre of land in a rotation are devoted to grain and forage. They reflect the major effects of the rotation on yields after it has been in effect for several years. Column 3 of the table shows the average reduction in production of grain with each pound of increase in production of forage. The negative substitution rates in the upper portion of the column denote a complementary relationship between forage and grain—each increase in production of forage is accompanied by an increase in production of grain. Increases in production of forage

[4] While the rotation results give only a few forage-grain combinations, additional combinations were derived by varying the acreage devoted to various rotations.

beyond 1,000 pounds per acre result in decreases in output of grain, that is, beyond this point forage and grain are competitive.

Forage-grain substitution rates for rotations may be related to the feed-substitution rates for livestock to determine the crop rotation and livestock ration which results in the largest production of livestock from a given acreage. If a grain-forage combination is to yield the largest output of a livestock product from a given acreage of land, two conditions must be met: The rate at which forage replaces grain in the crop rotation is equal to the rate at which forage substitutes for grain in the livestock ration; and the proportion of forage in the rotation is equal to the proportion of forage in the livestock ration. It can easily be demonstrated that only this set of forage-grain combinations will result in the maximum output of livestock from a given acreage.

Any decrease in the proportion of forage in the ration results in an increase in the replacement value of a pound of forage in terms of grain; but the reduction in the proportion of forage in the crop rotation decreases the substitution value of forage. Thus, in lowering the proportion of forage, the value of forage relative to grain as a feed increases, whereas the relative cost of forage decreases, making it profitable to substitute forage for grain. Movement in the opposite direction causes the substitution value of forage in the ration to decrease, whereas the cost of forage in terms of grain sacrificed increases, making it profitable to substitute grain for forage. For any forage-grain combinations for which rotation substitution rates are equal to the livestock ration substitution rates, any increase in either forage or grain involves a reduction in output of the other. It follows that the proportion of forage in the feed combination produced must be equal to the proportion of forage in the feed fed to livestock, if the livestock product from a given land area is to be a maximum. If the forage-grain ratios differ, a portion of one of the feeds is not fed—and the unused feed is produced at the expense of a reduction in the yield of the other feed.

A decision as to the forage-grain combination that will maximize the output of livestock from a given acreage may be illustrated for dairy cows by using the feed-combinations data for dairy cows in table 2 and the rotation data in table 6. Comparison of tables 6 and 2 shows that the substitution rate between forage and grain in the crop rotation is the same as that in the dairy ration at several forage-grain combinations. Similarly, the proportion of forage in the crop rotation is the same as the proportion of forage in the dairy ration at many different feed combinations. However, in only one set of forage-grain combinations are both the substitution rates and the forage-grain proportions equal. This set of combinations is a crop rotation that produces between 1,800 and 2,000 pounds of forage and a dairy ration that includes between 5,000 and 5,500 pounds of forage. The specific set of feed combinations for which both forage-grain substitution rates and forage-grain ratios are equal is a dairy ration that consists of 5,120 pounds of forage and 5,973 pounds of grain per cow and a crop rotation that yields 1,807 pounds of forage and 2,108 pounds of grain per acre. Each of these feed combinations contains 46.15 percent of forage; in each case 1 pound of forage substitutes for 1.46 pounds of grain.

NET RETURNS FROM 100 ACRES

This analysis shows the forage-grain combination that results in the largest livestock production from an acre of land. Generally, the crop rotation-livestock ration system that allows a maximum production of livestock from a given acreage also results in the largest net returns for a given expenditure of labor, equipment, and land. They may vary, however, with the prices of the products and the costs of the various production factors. Net livestock returns from 100 acres with the rotation and ration combination which allows the largest milk output per 100 acres and another forage-grain combination involving a higher proportion of forage are compared for two price periods in table 7.

TABLE 7.—*Costs and returns from livestock produced with two crop-rotation and livestock-ration systems on 100 acres of Marshall silt-loam soils, 1937–41, and 1944–48 prices*

Item	Maximum milk production system (35.3 cows)		Alternative system (28.2 cows)	
	1937–41 prices	1944–48 prices	1937–41 prices	1944–48 prices
	Dollars	*Dollars*	*Dollars*	*Dollars*
Gross return	5, 876	12, 231	4, 694	9, 771
Costs:				
Labor	1, 624	4, 307	1, 297	3, 440
Interest on investment:				
Livestock	199	453	159	362
Buildings and equipment	152	264	121	211
Feed:				
Production on farm [1]	1, 237	1, 816	1, 300	1, 940
Supplementary	106	198	85	158
Miscellaneous expense	193	310	155	247
Total	3, 511	7, 348	3, 117	6, 358
Net return	2, 365	4, 883	1, 577	3, 413
Investment:				
Livestock	3, 984	9, 056	3, 183	7, 234
Buildings and equipment	3, 794	6, 594	3, 031	5, 267
Total	7, 778	15, 650	6, 214	12, 501

[1] For estimates of crop production costs, see Heady, Earl O., and Jensen, H. R. (*4*).

On 100 acres of land of the type described in table 6, feeds consisting of 180,700 pounds of forage and 210,800 pounds of grain would be produced annually, if the crop rotation that allows maximum production of milk from the 100 acres were followed. This quantity of feed would support 35.3 dairy cows, each producing 8,500 pounds of milk annually, on a ration of 5,120 pounds forage and 5,973 pounds grain. If a different ration—one consisting of 8,500 pounds of forage and 3,156 pounds of grain, for example—were used, the 100 acres would

209706—52——3

provide feed for only 28.2 cows producing 8,500 pounds of milk each. About 125 acres would be required to produce this heavier forage ration for 35.3 cows producing 8,500 pounds of milk per cow.

The crop-rotation and dairy-ration system which supports the largest number of cows per 100 acres provides higher net returns than the system that involves fewer cows, even though it requires a larger expenditure of labor and a higher capital investment. The difference in net returns is smaller, however, with 1937–41 prices than with 1944–48 prices.

If the risk or uncertainty involved in the forage-grain combination which results in the greatest output of milk were greater than for a system that supports fewer cows, it still might be wise for some farmers to follow a system of farming which yields less than the maximum output of milk. However, as is shown in a later section of this report, the differences in risk and uncertainty in terms of variability of net livestock returns among different forage-grain feeding combinations would not be important.

It should be emphasized that the above-mentioned figures related to a particular soil type and one level of production per cow. Returns may differ greatly for other soil types where forage and grain substitute at different rates, for dairy cows producing at higher or lower levels, or for cows having productive capacities that differ from those used in this analysis. Also, the above-mentioned analysis is for a single livestock enterprise. Many farmers attempt both to combine enterprises and to arrange systems of feeding so that feeds and other resources can be most efficiently utilized.

It is true that most farmers have an opportunity to buy and sell grain, and that many can also buy or sell forages. Thus many farmers are not interested in obtaining the maximum livestock product from a given area. It may be as well to sell some of their grain as to feed it to livestock, or to feed more grain or forage than they produce.

CAPITAL AND LABOR REQUIREMENTS OF FEED-UTILIZATION SYSTEMS

Data presented in previous sections suggest the nature of feed relationships in livestock production, but they do not indicate the labor and capital requirements for different feeding systems. In the sections that follow, analysis is made of the capital and labor requirements for a few of the possible forage-grain combinations for each of several classes of livestock. The systems considered are either common in the Corn Belt or they present possibilities in the utilization of forage crops. A brief description of these systems follows:

Dairy Cows.—Feed requirements and production of milk for the different systems of feeding dairy cows are based on the study of input-output relationships in milk production cited on page 45 (*8*). Four forage-grain feed combinations are analyzed. The first combination consisted of cows on a high-grain ration. They received 40 percent of their feed (on a dry-weight basis) in the form of grain. They produced 399 pounds of butterfat each annually. The second combination consisted of cows fed a medium-high grain ration. They obtained 30 percent of their feed from grain. These cows produced

374 pounds of butterfat. Cows in the next combination were given a medium-high forage ration. They received only about 15 percent of their feed as grain. Their annual average production of butterfat was 323 pounds. Dairy cows handled according to the fourth system received only forage. Their annual average production of butterfat was 258 pounds.

Feeder Cattle.—Five feeder-cattle systems are analyzed. One involved the purchase of good-choice calves weighing about 440 pounds in October, wintering them, then feeding them out in dry lot. They were sold as choice cattle in August at a weight of about 1,000 pounds. Feed requirements and production for this system were based on results reported by the Iowa Agricultural Experiment Station (*1*).

Another feeder-cattle system involved the purchase of choice 2-year-old steers weighing about 800 pounds in August. They were pastured for a month in the fall and then put in dry lot and finished. They were sold in January as choice cattle weighing 1,150 pounds. Feed requirements and production under this feeding system are also adapted from the Iowa report (*1*).

Three systems of feeding yearling steers are compared. Feed requirements in each case were based on experiments conducted in Page County, Iowa, from 1946 to 1950 (*7*). In these experiments, yearling steers were bought in November and wintered to gain about a pound a day. In May one lot was placed in dry lot. These cattle were sold in October as choice cattle weighing 1,060 pounds. A second lot received somewhat more forage. They were pastured for 60 days, full-fed corn while on pasture for an additional 90 days, then finished in dry lot for sale in October as choice cattle weighing 1,120 pounds. A third group received a high proportion of forage in its ration. Feeders in this lot were placed on alfalfa-brome pasture and grazed continuously for 130 days. They were then placed in dry lot, brought to a full feed of corn, and finished to sell in December as choice cattle at a weight of 1,135 pounds.

Beef Herd.—Two systems of handling beef-breeding herds are examined. The first involves production of a 400-pound calf for sale in October. In the second system, the cows are handled as under the first, but the calves are fed out instead of sold as feeders. Calves are wintered through two winters and grazed one season and part of the second. They are then full fed in dry lot from July to September of the third year and sold as good-grade cattle weighing about 1,200 pounds (*6*, *9*).

Hogs.—Six systems of handling hogs are considered. Feed requirements for three are based on results of experiments with chopped hay by the United States Department of Agriculture at Beltsville, Md. (*3*). All the hogs in this experiment were fed in dry lot. One group received no hay. Those in the second lot received 10 percent of their feed in the form of chopped hay. Of the feed fed the pigs in the third lot 20 percent was chopped hay.

The three remaining hog-feeding systems are based on pasture experiments conducted by the Iowa Agricultural Experiment Station.[5]

[5] From unpublished data from Iowa Agricultural Experiment Station project No. 101.

Of the pigs in this experiment, those in the first lot received no pasture, those in the second lot received grain equal to 3 percent of their body weight while on pasture, and those in the third lot were given grain equal to only 1 percent of their body weight while on pasture.

Labor Requirements

In analyzing the feeding systems and crop rotations that maximize returns, emphasis was placed on the greatest output of livestock product from a given acreage, or the production of a given quantity of livestock product with the least possible cost for feed. This procedure is justifiable in the sense that costs of feed make up the greater part of total costs in livestock production. Other production factors are also important, however. Next to feed, labor makes up perhaps the largest single item of cost for all livestock, and in the case of dairy cows it constitutes an important portion of total costs. As costs of labor for any one type of livestock vary, depending on the system of feed utilization, consideration of the labor factor is important. Accordingly, this section relates labor requirements to different livestock rations.

If the feeds fed are grown on the farm, the forage-grain utilization system selected may affect labor requirements in both crop and livestock production. The effect of the utilization system on crop labor depends mainly on the way in which the forage is harvested (whether pastured or made into hay).[6] Increasing the proportion of forage in the ration fed a particular kind of livestock may affect labor requirements for livestock in three ways: (1) It may reduce the daily rate of production and thereby prolong the time an animal must be kept in order to produce a given output; (2) it may affect the daily labor requirements for feeding and caring for an animal; and (3) it may affect the distribution of the work load throughout the year.

LABOR REQUIREMENTS IN RELATION TO FEEDING SYSTEM

When labor is available, or can be hired, the objective is often one of minimizing the combined labor and feed cost of producing a particular output of livestock product. If labor requirements in producing 100 pounds of pork, for example, do not differ under different rations, the feed combination with the lowest feed cost will be the one that minimizes the cost of both feed and labor. If labor requirements change proportionately with changes in the proportion of forage in the ration, the analysis is still not difficult; the cost of forage can then be adjusted to include the additional labor costs associated with it. The optimum ration will be the one that minimizes the adjusted feed costs for a given output. Analysis is made more complex, however, when labor requirements do not vary proportionately with changes in the ratio of forage to grain in the ration. As shown in table 8, labor requirements do not generally vary in direct proportion with the amount of forage in the ration. Yearling steers fed a moderate

[6] However, on the basis of other studies in this connection it is assumed that the effect of changes in the rotation on labor requirements in crop production is unimportant. Here only the effects on labor needed for producing livestock with alternative rations are considered.

amount of forage required considerably more labor than either those handled on the high-grain ration or those fed a high proportion of forage. Also, labor requirements per dairy cow are shown to decrease as the proportion of forage in the ration increases. This is primarily because of the higher milk production per cow on the high-grain rations. Labor requirements per pig increase as the proportion of forage in the ration is increased. This increase is due to the extra work involved in handling the bulkier feeds in the case of hogs fed chopped hay and to the longer feeding period in the case of hogs fed on pasture.

SEASONAL DISTRIBUTION OF LABOR

Distribution of labor requirements must be considered in deciding the best feeding system if farmers are to avoid periods of low employment as well as periods that require the hiring of additional labor. The estimated monthly distribution of labor requirements for alternative feeding systems are shown in table 8. The percentage of the total labor required each month for handling dairy cows is not affected appreciably by the proportion of forage in the ration. In the case of yearling steers, the systems that involve a higher proportion of forage in the ration require a higher proportion of labor in fall months and considerably less labor in summer months, when the cattle are on pasture. Of the various hog-feeding systems considered, hogs fed different proportions of forage in the form of chopped hay in dry lot exhibit little differences in distribution of labor throughout the year. However, of hogs fed on pasture, those fed the higher proportion of forage require a somewhat longer production period and more labor in the fall than those fed little or no forage. In the case of hog production it is possible to vary the time of farrowing considerably and thus to arrange the work load to fit the availability of labor with any one of the several rations.

Returns From Labor

Labor is often a “rationed” factor. Many farmers are not in position to hire additional labor when they want it. Some lack facilities for keeping hired men. Some families may not be willing to share the home with hired labor. For a variety of reasons, many farmers want to keep labor requirements low and to distribute the work load in such a way that the need for hiring additional labor is minimized. A limited labor supply may restrict a farmer’s ability to utilize a large quantity of forage. Unless he has sufficient labor to expand his livestock systems to a size capable of consuming all the complementary forage produced, it will not be profitable to grow more than enough forage to bring total production of grain to a maximum. The labor required to consume the complementary forage through alternative feeding systems is consequently important in deciding whether it would pay to extend the grain-forage combination into the competitive range.

Column 2 of table 8 shows the total hours of labor that would be required to handle enough livestock to consume 100 tons of forage under each feed-utilization system. A farmer who produces 100 tons

TABLE 8.—*Labor requirements and percentage distribution of labor by months for utilization of 100 tons of forage, by kind of livestock and by feeding system*

Livestock and feeding system[1]	Labor		Percentage of total labor											
	Per head	Per 100 tons of forage consumed	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
	Hours	*Hours*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*
Dairy cows:														
High grain	200	9,000	11	10	11	10	8	6	6	6	6	7	9	10
Medium high grain	193	5,018												
Medium high forage	183	3,111												
High forage	176	2,640												
Feeder cattle:														
Calves, high grain	17.4	2,071	6	6	6	8	14	14	14	14	-----	6	6	6
Yearlings:														
High grain	15.3	872	3	3	3	3	16	16	16	16	16	2	3	3
Medium forage	19.0	589	3	3	3	3	3	16	16	16	16	16	2	3
High forage	10.9	251	5	5	5	5	2	2	2	2	22	22	25	3
2-year-old steers, high grain	12.6	2,293	16	-----	-----	-----	-----	-----	-----	16	17	17	17	17
Beef herd:														
400-pound calf, high forage	15.0	285	14	14	15	10	5	5	5	5	5	5	7	10
Calf fed out, high forage	33.0	363	12	12	12	10	3	3	10	10	10	3	7	8
Hogs:														
Dry lot:														
All grain	.59	-----	7	8	12	12	8	8	8	12	12	4	4	5
Medium forage	.65	2,990	7	8	11	11	9	9	9	12	12	3	3	6
High forage	.70	910	6	7	10	10	9	9	10	13	13	4	3	6
Pasture:														
All grain	.59	-----	7	8	12	12	8	8	8	12	12	4	4	5
Medium forage	.70	1,372	6	7	10	10	8	9	9	11	11	11	4	4
High forage	.80	960	6	6	9	9	7	7	9	10	10	11	11	5

[1] See pages 16 to 18 for a description of each system.

of forage in complementary relationship with grain would need 9,000 man-hours of labor to handle the 45 dairy cows required to consume that quantity of forage, if he follows the high-grain dairy ration. The same quantity of forage could be utilized with only 2,640 hours of labor if 15 milk cows were fed the high-forage ration. Only 251 hours of labor would be required to consume 100 tons of forage by feeding 23 yearling steers a high forage ration.

When labor is the limiting factor in production, in allocating it among alternative enterprises those livestock systems that require the smallest amount of labor per dollar of net income may well have priority. If labor is extremely limited, systems that are intensive in its use probably would not be selected. Table 9 compares the net returns that would be realized for 100 hours of labor applied to alternative feeding systems for each of three price periods. Hogs fed the all-grain ration in dry lot show the more favorable returns per 100 hours of labor for the three price periods indicated. But no forage is consumed by these hogs. If all available labor were applied to this livestock-feeding system, it would be profitable to extend production of forage through the complementary relationship, even if no return were realized from forage as a feed. But, while the returns per 100 hours of labor are substantially higher for hogs fed this ration than for any of the other classes of livestock, it does not

TABLE 9.—*Labor per head and net return per 100 hours of labor, specified price periods, by kind of livestock and by feeding system*

Livestock and feeding system [1]	Labor per head	Net returns per 100 hours of labor [2]		
		1931–35 prices	1937–41 prices	1944–48 prices
Dairy cows:	*Hours*	*Dollars*	*Dollars*	*Dollars*
High grain	200	10. 25	14. 31	22. 32
Medium high grain	193	2. 02	12. 15	25. 07
Medium high forage	183	−1. 88	9. 39	20. 56
High forage	176	−4. 42	7. 61	18. 13
Feeder cattle:				
Calves, high grain	17. 4	15. 63	66. 32	233. 90
Yearlings:				
High grain	15. 3	−29. 93	93. 07	313. 52
Medium forage	19. 0	3. 26	116. 37	316. 10
High forage	10. 9	24. 58	173. 39	613. 11
2-year-old steers, high grain	12. 6	70. 95	90. 32	135. 55
Beef herd:				
400-pound calf, high forage	15. 0	−89. 33	−5. 40	−104. 06
Calf fed out, high forage	33. 0	−43. 36	27. 70	83. 76
Hogs:				
Dry lot:				
All grain	. 59	137. 29	725. 42	1, 616. 95
Medium forage	. 65	98. 46	656. 92	1, 521. 54
High forage	. 70	22. 85	558. 57	1, 351. 47
Pasture:				
All grain	. 59	28. 81	574. 57	1, 098. 30
Medium forage	. 70	−2. 86	411. 42	1, 765. 71
High forage	. 80	−83. 75	231. 25	1, 223. 75

[1] See pages 16 to 18 for a description of each system.

[2] Net returns are computed as a residual after deducting all costs, including the cost of labor at the going wage.

necessarily follow that it would be most profitable to apply all the available labor on hogs.

Many other considerations, including the interrelationships among livestock enterprises, must be taken into account. What table 9 does suggest, however, is that with only a small amount of labor available it is profitable to apply a large portion of it to hogs before considering alternative systems.[7] With only a small amount of labor available for production of livestock, the most profitable use of that labor would involve little or no utilization of forage.

Capital Requirements

Time ordinarily elapses between the date that plans are made or production is initiated and the time when returns are realized. As a result, problems relating to capital investment arise in connection with farm production. As with any scarce resource, farmers have the problem of distributing their capital in a way that will maximize their net incomes. They may accomplish this by investing in each enterprise up to the point at which the returns from the last dollar of investment in each enterprise is equal to its cost. For farmers with adequate savings or unlimited borrowing power, this cost is represented by the returns obtainable on alternative investments off the farm or the interest charges that must be paid on borrowed capital. If available capital is limited, however, the investment in various enterprises is usually distributed in such a way that returns on the last dollar of investment in each enterprise are equal for all enterprises (although higher than the interest charge), if net income is to be a maximum.

As indicated in previous sections, it is profitable during a period of years to grow at least enough forage to bring total production of grain to its maximum. Production of complementary forage is profitable even though no return is realized on the forage as a feed. However, within a single year forage and grain are always competitive: increased acreage and production of forage can come only at the expense of grain (4). A shift of acreage from grain to grasses and legumes ordinarily means lower returns from grain in the few years that are required for the new rotation to influence yields of grain. If the additional forage is not utilized for feed, gross income to the farm is reduced to the extent of the reduction in returns from grain.[8] Thus some investment (postponement of income) is involved in extending the acreage of forage within the complementary range.

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[7] It should be kept in mind that, in computing the net income for each feed-utilization system, forage was charged at its market value. So long as the number of livestock on a farm is not adequate to consume all of the complementary forage this may represent too high a cost for forage: it may be more correct to consider forage as a free good in such a case. It is free in the sense that it would be wasted if not fed to livestock (cost of harvesting would need to be considered). Under such circumstances costs of feed for livestock that consume large quantities of forage would be substantially reduced. A beef herd, which can be maintained on practically an all-forage ration, might be quite profitable in such cases.

[8] Net returns may not be reduced by nearly so much, however, as the cost of harvesting the forage is avoided.

CAPITAL REQUIREMENTS IN RELATION TO FEEDING SYSTEM

An increase in acreage of forage beyond the point at which total production of grain is maximized is not profitable unless the additional forage is worth as much in terms of feed as the grain which it replaces. If the competitive forage is to have a value it must be sold or utilized through livestock. Use as feed involves establishing a livestock system large enough to consume all the forage. The size of the investment required to feed a given quantity of forage depends upon the kind of livestock to which it is fed and the proportion of forage in the ration.

Estimates of investment in livestock and necessary buildings and equipment required to utilize 100 tons of forage for the several types of livestock and feed-utilization methods are shown in table 10. The number of head of livestock needed to consume 100 tons of forage is based on estimated feed requirements for each of the feeding systems shown. The investment requirements are based on average Iowa prices for three different time periods. The years 1931 to 1935 were used to show investment requirements in a period of low price level. The period 1937 to 1941 was taken to represent a moderate price level. The years 1944 to 1948 were used as representative of a relatively high price level. Estimates of investments for buildings and equipment are based on minimum requirements for conditions in the Corn Belt.[9] Investment requirements were calculated on the basis of 100 tons of forage to be consumed. Any farmer can easily convert these figures to correspond to his own situation.

It is apparent from table 10 that alternative systems of feed utilization differ greatly in respect to the total capital required to buy (1) the livestock and (2) the buildings and equipment necessary to handle them.

In addition to these investments, "working capital" is often needed during the production period to pay for feed bought, labor hired, and such miscellaneous items as veterinary costs, taxes, supplies, and interest on borrowed capital. Estimates of the costs for production of livestock are given in table 11. As some of the costs are incurred on many farms well in advance of any returns, they are investments similar to those in livestock.

Cost values imputed to labor and feed resources used in livestock production (table 11), however, may exceed the actual amount of working capital required on some farms. In the case of dairy cows, for example, hired labor, commercial feeds, and miscellaneous supplies may be paid for from the monthly milk checks and the costs thus involve no working capital. Farm-grown feeds may not involve much outlay of funds, but holding them for feed ties up capital until the livestock is sold. Similarly, family labor used in production of livestock may not involve a direct outlay of funds, but, if alternative op-

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[9] It should be recognized that often investments in buildings are not required in order to establish a livestock system. On most farms some buildings can be adapted for use for the particular kind of livestock system to be followed. In such cases investment requirements for buildings and equipment would be lower.

TABLE 10.—*Investment in livestock and in buildings and equipment, specified price periods, for livestock to utilize 100 tons of forage, by kind of livestock and by feeding system*

Livestock and feeding system [1]	Livestock required	Investment					
		Livestock with price levels of—			Buildings and equipment with price levels of—		
		1931–35	1937–41	1944–48	1931–35	1937–41	1944–48
	Number	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*
Dairy cows:							
High grain	45	3, 166	5, 079	11, 544	4, 170	4, 836	8, 382
Medium high grain	26	1, 823	2, 935	6, 670	2, 401	2, 794	4, 843
Medium high forage	17	1, 162	1, 919	4, 361	1, 531	1, 827	3, 167
High forage	15	1, 037	1, 693	3, 848	1, 366	1, 612	2, 794
Feeder cattle:							
Calves, high grain	119	3, 538	4, 952	8, 845	5, 356	5, 975	10, 361
Yearlings:							
High grain	57	2, 273	3, 180	5, 884	2, 566	2, 862	4, 963
Medium forage	31	1, 236	1, 729	3, 200	1, 395	1, 557	2, 699
High forage	23	917	1, 283	2, 374	1, 035	1, 155	2, 003
2-year-old steers, high grain	182	9, 348	13, 168	24, 412	8, 183	9, 138	15, 847
Beef herd:							
400-pound calf, high forage	19	890	1, 551	3, 778	925	1, 037	1, 798
Calf fed out, high forage	11	673	821	1, 700	940	1, 012	1, 539
Hogs:							
Dry lot:							
All grain	-----	-----	-----	-----	-----	-----	-----
Medium forage	2, 855	6, 224	9, 364	24, 867	9, 136	10, 164	17, 644
High forage	1, 300	2, 834	4, 264	11, 323	4, 160	4, 628	8, 034
Pasture:							
All grain	-----	-----	-----	-----	-----	-----	-----
Medium forage	1, 960	4, 273	6, 429	17, 072	6, 272	6, 978	12, 113
High forage	1, 205	2, 834	3, 936	10, 452	4, 160	4, 272	7, 416

[1] See pages 16 to 18 for description of each system.

TABLE 11.—*Annual costs for specified price period to utilize 100 tons of forage, by kind of livestock and by feeding system*

Livestock and feeding system [1]	Labor costs with price levels of—			Feed costs with price levels of—			Other costs[2] with price levels of—		
	1931–35	1937–41	1944–48	1931–35	1937–41	1944–48	1931–35	1937–41	1944–48
Dairy cows:	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*
High grain	1, 469	2, 131	5, 660	3, 094	3, 579	8, 457	720	903	1, 697
Medium high grain	816	1, 184	3, 135	1, 964	2, 025	4, 392	416	522	981
Medium high forage	493	715	1, 895	1, 181	1, 142	2, 413	272	341	641
High forage	423	614	1, 626	863	772	1, 555	240	301	566
Feeder cattle:									
Calves, high grain	334	485	1, 284	4, 900	5, 610	12, 942	851	1, 017	1, 792
Yearlings:									
High grain	141	204	542	2, 562	2, 707	5, 982	401	491	828
Medium forage	89	129	342	1, 300	1, 380	3, 237	263	316	512
High forage	38	56	147	977	1, 009	2, 369	222	265	423
2-year-old steers, high grain	369	536	1, 420	3, 640	6, 296	14, 648	1, 301	1, 572	2, 808
Beef herd:									
400-pound calf, high forage	46	66	176	543	528	1, 304	167	212	439
Calf fed out, high forage	69	82	210	713	736	1, 521	213	237	383
Hogs:									
Dry lot:									
All grain	-	-	-	-	-	-	-	-	-
Medium forage	2, 998	4, 340	11, 506	26, 494	33, 089	76, 171	6, 281	6, 073	10, 135
High forage	1, 469	2, 132	5, 642	12, 480	15, 275	34, 710	2, 951	3, 198	4, 732
Pasture:									
All grain	-	-	-	-	-	-	-	-	-
Medium forage	2, 019	2, 979	7, 899	17, 032	21, 599	52, 391	4, 077	4, 528	7, 644
High forage	1, 350	1, 968	5, 208	10, 621	12, 420	30, 000	2, 652	2, 940	4, 992

[1] See pages 16 to 18 for description of each system.
[2] Includes depreciation and repairs for buildings and equipment, interest on investment, and miscellaneous costs.

portunities exist for the employment of this labor, the labor used during the production period involves a postponement of income.[10]

Many farmers lack capital to keep enough livestock to consume all the forage produced, even though the livestock system requiring the smallest investment of capital is adopted. If capital is extremely limited it may be impossible to invest in any livestock. But it would still be profitable to produce forage in the complementary range even though capital were not available to buy the livestock to use the forage. Livestock enterprises can be gradually built up to utilize the forage profitably with a very small initial investment. If, for example, a farmer has funds enough to buy a few heifers he can gradually accumulate a herd of cows. Although the heifers cannot consume all of the complementary forage at the start, an increasing quantity of it can be utilized as a larger herd of cows is accumulated.

Returns on Investment in Relation to Feeding System

Minimizing the capital investment is not the only nor even the most important goal. The objective is more nearly one of getting the greatest return per dollar of investment. This may sometimes be obtained with a system other than the one that requires the smallest investment per ton of forage consumed.

A comparison of the estimated annual net income per $100 of investment associated with alternative feeding systems is given in table 12. In each of the three price periods considered, hogs gave substantially higher returns per dollar of investment than other classes of livestock. In 1944–48, for example, hogs on pasture that received a moderate quantity of forage returned a net income of $83.01 annually per $100 of investment. This was well above the returns obtainable from a similar investment in any of the other types of livestock considered. But capital limitations may keep many farmers from establishing a hog enterprise of sufficient size to utilize all the complementary forage. An initial investment of $17,072 in livestock alone was required in 1944–48 to establish a hog enterprise large enough to consume 100 tons of forage in the form of pasture. In addition, an investment of $12,113 was required to provide buildings and equipment for an enterprise of this size when these facilities were not already provided. Furthermore, the returns for each class of livestock were computed on the basis of average operations. As the number of hogs handled on a farm increases diminishing marginal returns can be expected.

On Corn Belt farms, a combination of livestock enterprises ordinarily is more profitable than a single type of livestock.[11] Availability of labor at critical periods, lack of space or facilities, and other factors place practicable limitations on the extent to which a single enterprise can be expanded. Although a farmer may be unable to utilize all his forage with hogs alone, hogs give a high return relative to other feed-

[10] On many farms the labor used in production of livestock has no alternative use. For those farms the labor cost shown in table 11 greatly overvalues the labor required to handle the livestock. Computed costs of feed may also be a good deal too high for farms that do not have an alternative market for forage.

[11] This study does not undertake to determine the optimum combination of livestock on a farm. Other studies under way by Iowa State College and the Bureau of Agricultural Economics analyze problems of livestock combination.

Table 12.—*Annual net returns from livestock, in specified price periods, by kind of livestock and by feeding system*

Livestock and feeding system [1]	Net returns								
	Per head with price levels [2] of—			Per $100 investment					
				In livestock, buildings, and equipment with price levels [2] of—			In livestock with price levels [3] of—		
	1931-35	1937-41	1944-48	1931-35	1937-41	1944-48	1931-35	1937-41	1944-48
Dairy cows:	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*
High grain	20. 50	28. 62	44. 73	12. 71	12. 99	9. 88	38. 71	31. 72	22. 30
Medium high grain	3. 91	23. 44	48. 39	2. 42	10. 64	10. 69	14. 87	27. 13	27. 73
Medium high forage	−3. 45	17. 18	37. 62	−2. 14	7. 80	8. 31	4. 30	21. 58	19. 53
High forage	−7. 79	13. 39	31. 91	−4. 83	6. 08	7. 05	−1. 94	18. 22	17. 30
Feeder cattle:									
Calves, high grain	2. 72	11. 54	40. 79	3. 64	12. 56	25. 22	14. 46	35. 83	54. 57
Yearlings:									
High grain	−4. 58	14. 24	47. 97	−5. 39	13. 43	25. 21	−. 55	36. 92	56. 58
Medium forage	. 62	22. 11	60. 06	. 73	20. 86	31. 56	16. 00	52. 16	68. 66
High forage	2. 68	18. 90	66. 83	3. 16	17. 83	35. 12	22. 29	47. 36	75. 73
2-year old steers, high grain	8. 94	11. 38	17. 08	9. 27	9. 28	7. 72	43. 48	21. 93	18. 59
Beef herd:									
400-pound calf, high forage	−13. 40	−. 81	−15. 61	−13. 96	−. 59	−5. 32	−15. 16	9. 67	1. 48
Calf fed out, high forage	−14. 31	9. 14	27. 64	−9. 76	5. 48	9. 37	1. 68	26. 86	29. 58
Hogs:									
Dry lot:									
High grain	. 81	4. 28	9. 54	15. 06	62. 57	64. 07	55. 05	143. 60	117. 10
Medium forage	. 64	4. 27	9. 89	11. 89	62. 57	66. 42	47. 25	143. 29	122. 27
High forage	. 16	3. 91	9. 46	2. 97	57. 16	63. 53	25. 23	132. 32	117. 33
Pasture:									
High grain	. 17	3. 39	6. 48	3. 15	49. 56	43. 52	25. 69	116. 46	83. 12
Medium forage	−. 02	2. 88	12. 36	−. 37	42. 11	83. 01	16. 97	100. 91	150. 63
High forage	−. 67	1. 85	9. 79	−12. 45	27. 05	65. 75	−12. 84	69. 51	121. 12

[1] See pages 16 to 18 for description of each system.
[3] Net returns above feed, labor, interest, and miscellaneous costs.
[3] Net returns above all costs except those for buildings and equipment.

ing systems considered and offer an opportunity for profitable utilization of forage (table 12). Some of the other systems compared in table 12 require relatively low investments to consume a given quantity of forage—for example, beef-herd systems and the high-forage-ration dairy system—but returns per dollar of investment are lower than for hogs.[12]

TIMING OF INVESTMENT AND RETURNS

Many farmers place a high premium on present income; they are reluctant to invest if they cannot expect quick returns. This situation particularly characterizes beginning farmers who are short of capital and tenant operators who are not assured of being able to remain on a particular farm for more than 1 or 2 years. Unless returns on an investment can be realized within that time, the tenant may not be able to realize any return at all.[13] Other farmers can be indifferent as to the time span involved before returns on new investments are realized. As the timing of returns is more important to some classes of farm operators than others, data have been derived to indicate the length of time required for a turn-over of capital under the different feeding systems.

The length of time it would take to pay for the original investment in livestock from income remaining after paying for feed, labor, and miscellaneous costs of production if prices stayed at their 1944–48 level is shown in table 13. The length of time required to pay for the initial investment in buildings and equipment as well as for livestock from returns above all production costs is shown in table 14. In these comparisons, the original investments are assumed to be retained in each enterprise year after year. It is recognized, however, that any livestock enterprise can be liquidated at any time and at least a portion of the investment recouped. In the case of feeder cattle, this is done at the end of each production period.

Data in tables 13 and 14 are presented separately for these reasons: On many owner-operated farms, buildings have been provided in previous time periods. If not used for livestock they would stand idle. On most rented farms, buildings are provided by the landlord at no cost to the operator. In such situations only the rate at which investments in livestock are regained needs to be considered by the operator (table 13). Investments in buildings and equipment are not relevant. But on many farms operators may not be able to adopt livestock enterprises unless they provide buildings and equipment.

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[12] The data in table 12 may under some circumstances underestimate the returns per $100 investment obtainable from feeding systems that involve a high proportion of forage because the value of forage fed was imputed at the market price. If, as is often the case, no market exists for the sale of forage this imputed value may be too high. In that case the real cost of the forage may be the cost of harvesting and feeding it. Where the forage is fed as pasture this cost may be very small. Livestock systems that utilize large quantities of pasture forage may be considerably more profitable in such cases than is indicated in table 12.

[13] Many owner operators and landlords may also plan on the basis of a very short span. Owner operators or landlords who are advanced in age and who do not look forward to many additional years may take a "short-term" view. They may prefer to get as much income as possible in the near future to increase values in their estates.

TABLE 13.—*Percentage of initial investment in livestock recovered in specified time periods at 1944–48 prices, by kind of livestock and by feeding system* [1]

Livestock and feeding system [2]	Percentage of investment recovered by end of—									
	3 months	6 months	9 months	1 year	2 years	3 years	4 years	5 years	6 years	7 years
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Dairy cows:										
High grain	5. 56	11. 15	16. 71	22. 30	44. 60	66. 90	89. 20	111. 40	--------	--------
Medium high grain	5. 93	11. 87	17. 80	23. 73	47. 46	71. 19	94. 92	118. 65	--------	--------
Medium high forage	4. 88	9. 77	14. 65	19. 53	39. 06	58. 59	78. 12	97. 65	117. 18	--------
High forage	4. 32	8. 65	12. 97	17. 38	34. 60	61. 90	69. 20	86. 50	103. 80	--------
Feeder cattle:										
Calves, high grain	--------	--------	--------	54. 57	109. 14	--------	--------	--------	--------	--------
Yearlings:										
High grain	--------	--------	--------	56. 58	113. 16	--------	--------	--------	--------	--------
Medium forage	--------	--------	--------	68. 66	137. 32	--------	--------	--------	--------	--------
High forage	--------	--------	--------	75. 73	151. 46	--------	--------	--------	--------	--------
2-year-old steers, high grain	--------	18. 59	18. 59	37. 18	74. 36	111. 54	--------	--------	--------	--------
Beef herd:										
400-pound calf, high forage	--------	--------	--------	1. 48	2. 98	4. 44	5. 92	7. 40	8. 88	10. 36
Calf fed out, high forage	--------	--------	--------	--------	--------	29. 58	59. 16	118. 32	--------	--------
Hogs:										
Dry lot:										
All grain	--------	--------	--------	117. 10	--------	--------	--------	--------	--------	--------
Medium forage	--------	--------	--------	122. 27	--------	--------	--------	--------	--------	--------
High forage	--------	--------	--------	117. 33	--------	--------	--------	--------	--------	--------
Pasture:										
All grain	--------	--------	--------	83. 12	166. 24	--------	--------	--------	--------	--------
Medium forage	--------	--------	--------	150. 63	--------	--------	--------	--------	--------	--------
High forage	--------	--------	--------	126. 12	--------	--------	--------	--------	--------	--------

[1] See table 10 for investment in livestock and table 12 for returns above feed, labor, interest and miscellaneous costs.

[2] See pages 16 to 18 for description of each system.

TABLE 14.—*Percentage of initial investment in livestock, buildings, and equipment recovered in specified time periods at 1944–48 prices, by kind of livestock and by feeding system*

Livestock and feeding system [1]	Percentage of investment recovered by end of—				Years required to recover 100 percent of investment
	2 months	6 months	9 months	1 year	
Dairy cows:	*Percent*	*Percent*	*Percent*	*Percent*	*Number*
High grain	2.47	4.94	7.41	9.88	11
Medium high grain	2.67	5.31	8.01	10.69	10
Medium high forage	2.08	4.15	6.23	8.31	12
High forage	1.76	3.52	5.28	7.05	15
Feeder cattle:					
Calves, high grain	-------	-------	-------	25.22	4
Yearlings:					
High grain	-------	-------	-------	25.21	4
Medium grain	-------	-------	-------	31.56	4
High forage	-------	-------	-------	35.12	3
2-year-old steers, high grain	-------	7.72	7.72	7.72	13
Beef herd:					
400-pound calf, high forage	-------	-------	-------	−5.32	(2)
Calf fed out, high forage	-------	-------	-------	(3)	13
Hogs:					
Dry lot:					
High grain	-------	-------	-------	64.07	2
Medium forage	-------	-------	-------	66.42	2
High forage	-------	-------	-------	63.53	2
Pasture:					
High grain	-------	-------	-------	43.52	3
Medium forage	-------	-------	-------	83.01	2
High forage	-------	-------	-------	65.75	2

[1] See pages 16 to 18 for description of each system.
[2] On the basis of 1944–48 cost and price relationships, the beef-herd system failed to cover costs each year.
[3] Returns would not be realized from this system until the third year.

Data in table 14, which show the time required to replace the total investment from returns above costs of production, are of interest in such situations.

The timing of returns from various feeding systems has two aspects: (1) The length of time required to replace the original investments for establishing the various feed-utilization systems, and (2) the nature of the flow of returns during the production period for each feeding system. On the basis of assumed 1944–48 price relationships, it would take 5 to 6 years to replace the investment in dairy cattle from net returns, and from 10 to 15 years to replace the investment in dairy cows and the buildings and equipment necessary for handling them. It would take 67 years to replace the original investment in beef cows for the feeding system that involves production of 400-pound feeder calves. When investments in and costs of buildings and equipment are included, net returns from this system are negative. But on the basis of 1944–48 prices the hog-feeding systems would provide net returns over costs sufficient to replace the investment in brood sows and buildings and equipment within 2 years. Farmers who need not invest in buildings and equipment in order to establish a hog system could replace their initial outlay of capital

at the end of 1 year's operation without reducing the size of the enterprise.

Feeder-cattle systems, except those for 2-year-old steers, required only 3 or 4 years to replace the initial investment in buildings and equipment and feeders. They need only 2 years to replace the initial investment in livestock from returns above costs of feed, labor, and miscellaneous expenses. Two-year-old steers required 13 years to replace all investments and 3 years to replace the investment in livestock.

The nature of the flow of returns from the various feeding systems may be important to some farmers. Dairy systems provide a fairly steady stream of income during the year at weekly or monthly intervals, which makes it possible to pay as you go for labor, feed, and other production expenses. Returns from hogs, feeder cattle, and beef cows come at less frequent intervals. This often makes it necessary to borrow money to meet operating costs and expenses for family living while production is in process.

The procedure followed in tables 13 and 14 is useful in comparing the relative rate at which returns are realized on investments in alternative feeding systems for the set of price relationships employed. But the time required for livestock to return the initial investment varies with the level of prices. Figure 1 compares the time required to return the initial investment in livestock with prices at the levels of 1930 and 1940. It is apparent that the timing of the original investment with respect to prices is equally as important as type of livestock in determining the rate of turn-over of capital. The period

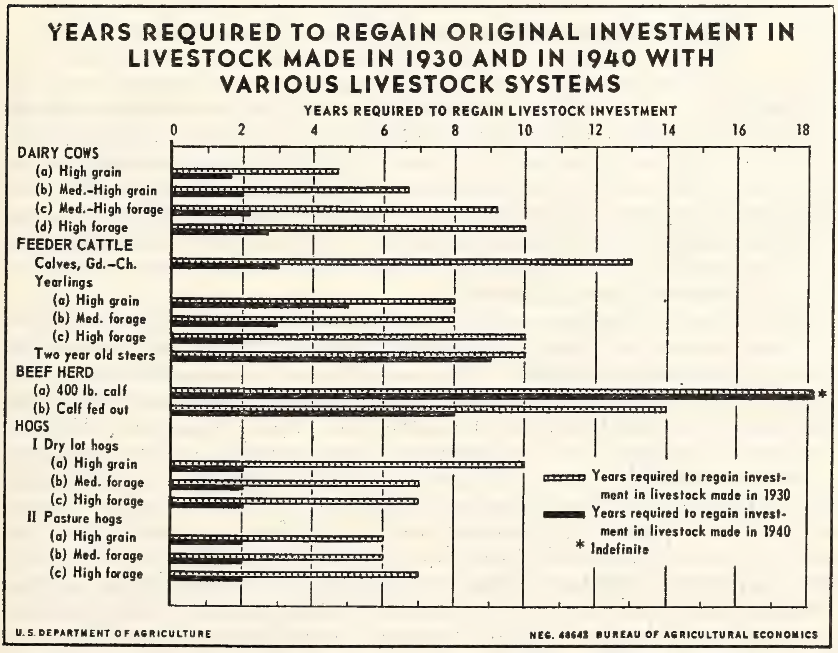

FIGURE 1.—Years required to regain original investment in livestock made in 1930 and in 1940 with various livestock systems.

required to replace an initial investment made in each livestock feeding system in 1930 was about three times as long as that required to replace a similar investment made in 1940.

RELATIONSHIP OF FEED-UTILIZATION SYSTEM TO RISK AND UNCERTAINTY

In the organization of a farm the risk element is important. Beginning farmers or those with low capital equities may prefer a livestock system that provides a steady return—one that does not result in large losses, even though average returns may be relatively low. Occasional large losses are not so important to farmers who have ample capital if average returns are relatively high. If losses are incurred in one year, their capital position will allow them to remain in farming to gain the high returns in later years. But if a farmer who is short of capital loses heavily one year he may have to close down his business before the big rewards are forthcoming.

Farmers often express the idea that different feed-utilization systems involve different degrees of risk or uncertainty. High-forage rations may involve greater risk or uncertainty because of (1) the greater capital invested per dollar of returns and (2) the added time required to produce 100 pounds of livestock or livestock product. In this section, some estimates are made of the degree of risk or uncertainty involved in different utilization systems. The data are for the same livestock systems that were considered above.

Feed Combinations and Market Uncertainty

Risk and uncertainty undoubtedly play an important part in farmers' judgments of the relative desirability of alternative systems of utilizing feed. Their individual attitudes toward risk and uncertainty may be influenced by financial position, previous training or experience, and such personal traits as timidity, desire to gamble, and love for adventure. Most farmers probably are as much concerned with the degree of uncertainty associated with alternative investments as they are with the relative average returns that can be expected from each investment through the years.

How does the presence of risk and uncertainty affect selection of the most desirable grain-forage combination? To most farmers the ideal combination would be the one that returns maximum profit over time and involves the least risk. Unfortunately, a system that combines these qualities may be more than can be expected. Higher returns will often be at the expense of greater risk and uncertainty.

As forage is substituted for grain in the livestock ration the length of the production process tends to increase. That is, it takes longer to produce a pound of livestock product by feeding forage than by feeding grain. Extending the time involved in production may have two important effects. First, it may cause the marketing of the product to fall into a period of lower seasonal prices. This problem can ordinarily be handled by a change in the timing of production; for example, the date of farrowing may be adjusted. A second possible consequence of extending the production period is that market

uncertainty may be increased. As the time is increased between the date plans are made and the time the product is sold the chance increases that actual prices and costs will deviate from those on which the plans were based.

MEASUREMENT OF MARKET UNCERTAINTY

It is apparent that the degree of risk and uncertainty associated with different feeding systems must be compared in the final determination of the best system. Under conditions of true uncertainty no objective measure is possible; the outcome is one of the future. How then can uncertainty be measured? One possible indicator is the historic variability in returns from each feeding system. If the returns from a particular feeding system have shown a great deal of fluctuation in the past, it appears likely that they will also vary a great deal in the future. (This procedure supposes the future to be some rough counterpart of the past.)

Using this method of measurement, some idea of the effect of substituting forage for grain in livestock rations on risk or uncertainty can be gained from the information in tables 15, 16, and 17, which show the variation in returns from each of several livestock-feeding systems for dairy cows, feeder cattle, and hogs for the years 1917 through 1948. The returns in table 15 refer to returns per $100 of all cost. Returns in table 16 are per $100 of costs for feed and labor only. Table 17 shows returns per $100 of feed costs only. These estimates of returns were made on the basis of actual prices for each of the years applied to the product produced under each system. Costs were estimated by applying annual prices to the quantities of the various resources used. Inputs of resources for each system were estimated, assuming present techniques. Thus the data show only the variations in returns that were due to changes in costs of factors and prices of products. They do not reflect the variations due to fluctuations in production.

Two aspects of the variation in returns that is associated with alternative feeding systems are (1) the amount of variation and (2) the way in which returns are distributed above and below the average. Two feeding systems that give the same average returns during a period of years and for which returns vary similarly about the average may involve quite different degrees of uncertainty. Returns under one system may fluctuate between 70 percent below average and 30 percent above average, whereas the other system may provide returns that vary between 30 percent below average and 70 percent above average. Clearly the chances of big losses are much greater with the first system. Also, the chances of big gains are much less.

VARIABILITY OF RETURNS IN RELATION TO LIVESTOCK RATIONS

The degree of variation in returns shown in tables 15, 16, and 17 for the different feeding systems for each class of livestock are examined first.

Each table shows two things: (1) The returns from each feeding system for each class of livestock are distributed in a remarkably even pattern above and below the average returns for the respective feeding system; and (2) the degree of variation is not greatly affected

TABLE 15.—*Frequency distribution of returns and average returns per $100 of all costs for various livestock-feeding systems, 1917–48*

Livestock and feeding system [1]	Years during period when dollar return per $100 of all costs was [2]—												Average return per $100 of all costs [2]
	0–19	20–39	40–59	60–79	80–99	100–119	120–139	140–159	160–179	180–199	200–219	220–239	
	Number	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Dollars*
Dairy cows:													
High grain					4	11	15	2					119
Medium high grain					7	10	15						113
Medium high forage					7	17	8						109
High forage					11	15	6						105
Feeder cattle:													
Calves, high grain		1	2	4	3	12	6	4					106
Yearlings:													
High grain		1	1	6	9	6	2	6			1		104
Medium forage		1		6	6	7	5	3	3		1		112
High forage		1	2	3	6	9	2	4	3	1		1	113
2-year-old steers, high grain	1		2	6	9	3	3	5	3				103
Hogs:													
Dry lot:													
All grain				2	4	10	9	4	2	1			122
Medium forage				3	3	10	10	3	2	1			121
High forage			1	2	3	13	7	3	2	1			118
Pasture:													
All grain			1	2	6	11	7	4	1				114
Medium forage			1	2	4	10	7	5		2	1		122
High forage			1	2	7	8	8	3	2	1			115

[1] See pages 16 to 18 for a description of each system.

[2] Cost items include feed, labor, interest, and miscellaneous costs.

TABLE 16.—*Frequency distribution of returns and average returns per $100 of feed and labor costs for various livestock-feeding systems, 1917–48*

Livestock and feeding system [1]	Years during period when dollar return per $100 of feed and labor cost was [2]— 0–19	20–39	40–59	60–79	80–99	100–119	120–139	140–159	160–179	180–199	200–219	220–239	240–259	260–279	Average return per $100 of feed and labor cost [2]
	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	Dollars
Dairy cows:															
High grain	-----	-----	-----	-----	1	7	8	12	3	1	-----	-----	-----	-----	137
Medium high grain	-----	-----	-----	-----	2	9	8	13	-----	-----	-----	-----	-----	-----	130
Medium high forage	-----	-----	-----	-----	1	13	10	8	-----	-----	-----	-----	-----	-----	127
High forage	-----	-----	-----	-----	3	11	10	8	-----	-----	-----	-----	-----	-----	124
Feeder cattle:															
Calves, high grain	-----	-----	2	3	3	3	11	6	3	1	-----	-----	-----	-----	120
Yearlings:															
High grain	-----	1	-----	5	5	8	5	1	5	1	-----	-----	1	-----	118
Medium forage	-----	-----	1	1	5	7	6	4	2	5	-----	-----	1	-----	131
High forage	-----	1	1	1	4	6	7	1	3	4	2	1	-----	1	136
2-year-old steers, high grain	1	-----	1	2	6	7	3	4	4	1	1	2	-----	-----	129
Hogs:															
Dry lot:															
All grain	-----	-----	-----	1	1	6	10	4	6	1	3	-----	-----	-----	142
Medium forage	-----	-----	-----	1	1	4	12	4	6	2	2	-----	-----	-----	142
High forage	-----	-----	-----	1	2	7	8	7	3	3	1	-----	-----	-----	139
Pasture:															
All grain	-----	-----	-----	2	1	13	5	4	3	4	-----	-----	-----	-----	131
Medium forage	-----	-----	-----	1	2	9	6	3	4	2	3	2	-----	-----	144
High forage	-----	-----	-----	1	3	10	4	6	1	4	2	1	-----	-----	138

[1] See pages 16 to 18 for a description of each system.

[2] Feed and labor are only cost items considered in computing returns.

TABLE 17.—*Frequency distribution of returns and average returns per $100 of feed cost for various livestock-feeding systems, 1917–48*

Livestock and feeding system [1]	Years during period when dollar return per $100 of all costs was [2]—																Average return per $100 of feed cost [2]
	0–19	20–39	40–59	60–79	80–99	100–119	120–139	140–159	160–179	180–199	200–219	220–239	240–259	260–279	280–299	300–319	
Dairy cows:	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*Dollars*
High grain							3	3	4	7	5		4	4	1	1	219
Medium high grain							4	3	6	7	4	2	4	1	1		206
Medium high forage							5	3	7	5	6	1	3	2			203
High forage							2	4	4	7	6	1	2	2	2	2	218
Feeder cattle:																	
Calves, high grain			1	3	4	2	7	6	6	2	1						134
Yearlings:																	
High grain		1		4	5	5	7	3	1	5				1			127
Medium forage			1		6	2	9	3	3	3	2	2			1		144
High forage		1	1	1	3	5	7	2	3	4	1	2	1		1		144
2-year-old steers, high grain	1		1	1	5	7	3	5	4	1	1	2	1				136
Hogs:																	
Dry lot:																	
All grain				1	1	1	8	8	4	2	3	4					160
Medium forage				1	1	1	9	5	6	2	3	4					162
High forage				1	1	1	9	5	6	3	3	3					159
Pasture:																	
All grain				1	1	7	8	5	3	3	4						146
Medium forage				1	1	4	6	7	2	2	4		3	2			163
High forage				1	1	4	9	3	3	3	2	3	2	1			162

[1] See pages 16 to 18 for a description of each feeding system.

[2] Feed is only item of cost considered in computing returns.

by increasing the proportion of forage in the ration fed a particular class of livestock. In fact, dairy cows that were fed only forages showed somewhat less variation in returns per $100 of all costs than cows that were fed the high-grain ration. Yearling steers that were fed the high-forage ration had only slightly more variable returns than those that were fed the other two rations. The feeding systems for each class of livestock that showed the greatest variation in returns showed no greater chance of loss but a slightly greater chance of high returns. The difference in variability in returns among alternative feeding systems for any one kind of livestock was not great enough to be important. Thus the information in these tables suggests that the uncertainty associated with a livestock system is not appreciably affected by the substitution of forage for grain in the ration. Hence it appears that consideration of risk or uncertainty is not involved in the choice of a feeding system for a particular kind of livestock.

VARIABILITY OF RETURNS IN RELATION TO KIND OF LIVESTOCK

In dealing with the problem of feed utilization it is also useful to compare the variability of returns from alternative kinds of livestock. The data in tables 15, 16, and 17 indicate considerable differences in the variation in returns among the various classes of livestock. First, consider the variation in returns per $100 of all costs (table 15). The degree of variation was clearly less for dairy cattle than for hogs or feeder cattle. However, the frequency of losses (returns less than $100 per $100 of costs) was less and maximum losses were only a little greater for hogs than for dairy cows. High returns were much more frequent with hogs. That is, the chances of loss were no greater for hogs than for dairy cattle, and the opportunity for large gains was considerably greater for hogs.

A comparison between hogs and feeder cattle shows less variation in returns from hogs. The chances of heavy losses were greater with feeder cattle. Opportunities for large gains were about equal for the two classes of livestock. A comparison between dairy cows and feeder cattle shows that the chances of both heavy losses and large gains are much greater for feeder cattle. If the objective is primarily one of minimizing the chance of loss, hogs are apparently the desirable livestock to raise. Feeder cattle are least desirable from this standpoint.

The variability of returns per $100 of feed and labor is somewhat larger for all livestock systems than when all costs are considered (table 16). The pattern of the variation is very much the same, however—there still appears to be no relationship between variability of returns and substitution of forage for grain in the livestock ration. The relative variability of returns per $100 of feed and labor costs for the different livestock classes is similar to the situation in which the variabilities of returns per $100 of all costs are compared.

A comparison of the variability of returns from different livestock systems on the basis of cost of feed only is made in table 17. On this basis, the risk of losing money with dairy cattle is much less than with either feeder cattle or hogs. Even in the poorest years, dairy cows returned more than $120 per $100 worth of feed fed. Feeder

cattle failed even to cover costs of feed in 6 to 10 of the 32 years. Many farmers might well consider the uncertainty associated with alternative livestock enterprises in these terms. When family labor is plentiful and has little other opportunity for profitable employment, a low return to labor may be a small risk compared to the possibility of not being able to meet feed costs.

Adjustments to Changing Price Relationships

Comparison of the degrees of variability (risk) associated with alternative feeding systems has been made on the assumption that a particular feeding system is followed consistently through time. Actually, farmers need not follow the same system year after year. They may alter the proportion of forage in the ration from time to time. Also, there is often an opportunity to shift from one kind of livestock to another. However, once investments have been made in specialized buildings, equipment, or fences, it may be difficult or expensive to adapt these facilities to other kinds of livestock. Specialized knowledge and skills may be required for handling a particular kind of livestock and this may deter farmers from changing from one class of livestock to another. But changing from one ration to another is usually easy. Changes can be made quickly and usually with little alteration in facilities.

ADJUSTMENTS BETWEEN ENTERPRISES

The uncertainty involved in making investments for buildings, equipment, and other facilities is important. Many of these investments extend for years into the future. Facilities for handling different classes of livestock are more or less specialized and are often difficult to adapt to other uses. It follows that not only are price and cost anticipation for several years ahead subject to a great deal of error, but also it is often difficult to reverse decisions based on these expectations. For example, a farmer may believe that dairy products will bear cost and price relationships such that in the next 10 or 20 years it will be profitable to build a dairy barn, buy the necessary equipment, and stock his farm with a herd of good-quality dairy cows. He may find a few years hence that his anticipations were wrong and that feeder cattle, hogs, or beef cows show much better prospects for profit. But at this point it is not easy to turn back. The facilities and equipment used in dairy production are not well adapted to other kinds of livestock. Considerable investment may have gone into building up a herd. It may not be possible to recoup all of the investment in the dairy herd and to expand the hog or feeder cattle enterprises instead.[14]

ADJUSTMENTS BETWEEN RATIONS

Although it may not be feasible to change from one kind of livestock to another from year to year, adjustments are possible within a par-

[14] It is possible to plan facilities to permit greater flexibility between enterprises. Ordinarily, the better suited facilities are for a particular livestock, the less flexible is their use. Flexibility is often achieved at the expense of somewhat less efficient production for any one enterprise.

ticular class of livestock without much difficulty or expense. The amount of forage in the ration for each class of livestock can be varied within wide ranges. The feeder-cattle system can be varied in several ways. One can shift from yearlings to calves or 2-year-old steers, or from choice feeders to medium feeders, with little difficulty. Even within a production period, up to the time the livestock are marketed, adjustments can be made in the feed combinations fed. Uncertainty as to cost relationships tend to decrease as the date of sale of the livestock products approaches. Estimates of milk prices used in deciding to build the dairy barn may differ widely from the actual prices received for milk during the lifetime of the barn. But one can estimate more exactly the price that will be received for the milk produced from the hay and grain fed to a cow today. Thus price estimates formed at the beginning of each production period are likely to be a great deal more accurate than estimates of prices during a long period of years, which are the basis for a decision to establish a particular livestock system.

If expectation could be formed correctly at the beginning of each production period it would pay to adjust the feeding system for each class of livestock in accordance with the principles set down in previous sections of this report. That is, if the price of forage were expected to decline relative to grain, it would pay to follow a ration which included a high proportion of forage.[15] Table 18 shows how returns during 32 years would have been increased by making such adjustments from year to year. Hogs fed on pasture provide a good example. No single feed combination was most profitable in all of the 32 years. Hogs fed no forage were most profitable in 9 years; those fed a moderate quantity of forage proved most profitable in 18 years; and those fed a large proportion of forage gave highest returns above all costs in 5 of the 32 years.

If expectations as to prices and costs had been formed correctly by weaning time and the optimum feed combination selected accordingly, profits from the hog enterprise would have been greater than if any one of the three feeding systems had been followed consistently year after year. In this case, the returns per $100 of all costs would have averaged $124, slightly higher than the $122 realized by consistently following the ration that contained a moderate amount of forage. Average returns per $100 of costs from dairy cows would have been increased from $119 to $121 by adjusting to the most profitable ration instead of following the high-grain ration year after year. By selecting the most profitable of the five systems of feeding feeder cattle each year, returns would have averaged $132 per $100 of all costs as compared with only $113 by feeding yearling steers a high-forage ration each year. Also, the number of years in which returns failed to cover all costs would have been reduced from 12 to 7. The number of years in which returns would have been insufficient to cover costs of the feed would have been reduced from six to only two. Unfortunately, the possibility of anticipating price relationships correctly at the beginning of the feeding period is much greater for feeder cattle than for hogs or dairy cows.

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[15] Adjustments in the ration from time to time during the production process as estimates of cost relationships are revised are possible also.

TABLE 18.—*Frequency distribution of returns and average returns per $100 of specified costs for alternative feeding systems, 1917–48*

Livestock and feeding system [1]	Years with returns per $100 of—									Average returns per $100 by using most profitable feeding system [2] —		
	All costs			Feed and labor			Feed					
	Highest	Lowest	Minus	Highest	Lowest	Minus	Highest	Lowest	Minus	All costs	Feed and labor	Feed
Dairy cows:	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Dollars*	*Dollars*	*Dollars*
High grain	26	4	4	22	3	1	14	8	0			
Medium high grain	2	0	6	3	2	2	1	5	0			
Medium high forage	1	2	7	1	10	1	1	14	0	121	141	240
High forage	3	26	11	6	17	3	16	5	0			
All			2						0			
Feeder cattle:												
Calves	8	3	10	1	8	8	4	4	8			
Yearlings:												
High grain	0	10	17	0	7	11	0	12	10			
Medium forage	4	0	13	5	0	7	9	0	7	132	158	170
High forage	9	3	12	13	3	7	7	3	6			
2-year-old steers	12	15	18	13	14	10	12	13	8			
All			7			3			2			
Hogs:												
Pasture:												
All grain	9	16	9	5	21	3	3	24	2			
Medium forage	18	2	7	20	3	3	19	1	2	124	145	168
High forage	5	14	6	7	8	4	10	7	2			
All			6			3			2			

[1] See pages 16 to 18 for a description of each system.

[2] Average returns if most profitable feeding system for the kind of livestock in each year were followed rather than a single feed combination year after year. See tables 15, 16, and 17 for average returns from the same system of feeding during the 32-year period.

On the basis of these data, apparently for those farmers who are able to do a good job of predicting prices and costs there may be a substantial advantage in adjusting the feeding system for feeder cattle each year in accordance with expectations. Those who are not able to estimate future price relationships well will probably be better off if they follow one system consistently. According to these data, dairymen and hog producers would find only a small advantage in changing their feeding systems from year to year, even if they were able to predict future cost relationships accurately. It should be recognized, however, that the alternative feeding systems considered here represent only a few of the large number of possible feed combinations. It is possible that the most desirable combination, from the standpoint of profitability and risk or uncertainty, may differ from any of the feeding systems considered in this report.

ADJUSTMENTS IN LEVEL OF PRODUCTION

The foregoing analysis was concerned with selection of the best feed combination for given levels of livestock production. But along with selecting the optimum grain-forage combination, the individual farmer must decide whether to feed his dairy cows to produce, for example, 7,500, 8,500, or 10,000 pounds of milk. He must decide whether to sell his hogs at 200, 225, or 250 pounds. The most profitable level of production depends on the price of the product relative to the prices of the production factors, and on the response in production to the application of successive units of the productive factors. More precisely, the most profitable level of production is attained when the cost of adding the last pound of livestock product per animal just equals its price. Any change in either the price of the product or the cost of the factors of production will alter the optimum level at which to produce. As price and cost relationships change continually, selection of the level of production involves considerable risk and uncertainty.

As the production process progresses, a farmer may continually revise his estimates of prices in relation to costs and, up to the time of sale, he may make some adjustments in the level of production. For example, when his hogs reach a weight of 200 pounds he can decide whether it will pay to carry them to heavier weights. The closer he comes to the date of sale the better his estimates of prices will be. But even then he cannot predict exactly the price that will be obtained on a particular day, as day-to-day variations in prices are often large. Nevertheless, as additional information is ordinarily obtained as the production process progresses, estimates of expected price-cost relationships, and consequently the planned levels of output, are constantly revised. With each revision of the planned level or production, he needs to adjust the forage-grain combination in the ration if rates of substitution between feeds or the risk and uncertainty associated with various rations differ significantly.

SUMMARY

Grasses and legumes may contribute indirectly to farm income by increasing or maintaining yields of other crops during a period of

time. In addition, they have a direct value as a livestock feed. Farmers generally are aware of these benefits of forage in a farm organization, but problems of utilization make it difficult for many farmers to determine the profitability of further increases in production of forage.

Three basic sets of relationships determine the forage-utilization system that is most profitable for an individual farmer. These relationships are: (1) the rate at which forage substitutes for other feeds in the livestock ration and the rate at which forage substitutes for grain in the crop rotation; (2) capital and labor requirements; and (3) risk and uncertainty.

Rotation Relationships

Forage may be either complementary or competitive with grain in crop production. It is complementary if an increased acreage of forage causes total production of grain from a given area to increase. Forage is competitive with grain if greater acreage and production of forage is achieved at the expense of a decrease in total production of grain. Data examined in the study upon which this report is based show that when forage makes up only a small proportion of the acreage in a rotation it is complementary with grain—increases in the proportion of forage in the rotation result in increases in output of grain. Additional increases in the proportion of forage result in smaller increases in production of grain until eventually forage and grain become competitive—further increases in the proportion of forage results in less total production of grain.

The profitability of increasing production of forage beyond the point at which it becomes competitive with grain depends on the value of the increased forage relative to that of the grain which it replaces. On livestock farms the value of forage is influenced by its value as a livestock feed. Thus the relationships of grain to forage in the crop rotation and in the livestock ration are crucial to determination of the more profitable grain-forage combination.

Feed Substitution in Livestock Rations

Many livestock feeding experiments were examined in order to estimate the substitution rates between forage and grains as feeds. Only a few of these experiments provided data suitable for estimating the substitution rates. With the limited data, estimates were made of forage-grain substitution rates for dairy cows, feeder cattle, hogs, and sheep. Although more experimental work is needed before reliable estimates of the relationships between forage and grain in feeding different kinds of livestock under various conditions can be established, the estimates provided in this study suggest the nature of the feed-substitution relationships and provide an approximation to the substitution coefficients under certain conditions.

Forage was found to substitute for grain at a diminishing rate for each of the four kinds of livestock considered. For example, it was found that a cow will produce 8,500 pounds of 4-percent fat-corrected milk with 5,500 pounds of hay and 5,459 pounds of grain or with 4,933 pounds of grain and 5,959 pounds of hay—567 fewer

pounds of grain and 500 more pounds of hay. At that level of forage feeding, each additional pound of hay replaces 1.13 pounds of grain. Each additional 500 pounds of hay replaces fewer pounds of grain until as the quantity of hay is increased from 10,500 to 11,000 pounds, for example, the quantity of grain required is reduced only 138 pounds—or, a pound of hay replaces only 0.28 pound of grain at that level of forage in the ration.

Similar relationships were found for other classes of livestock. The replacement value of a pound of forage in feeding hogs was found to be about 0.5 pound of grain when the hog ration contained no forage; when the ration contained about 14-percent forage a pound of forage replaced about 0.12 pound of grain. In producing choice beef on yearling steers, a pound of forage was found to have a feeding value equal to about 0.4 pound of grain when the ration contained about 35-percent forage; when the forage amounted to about 85 percent of the ration a pound of forage replaced only 0.24 pound of grain. Analysis of lamb-feeding experiments showed that when the ration contained only 26-percent forage, 1 pound of forage replaced about 0.6 pound of grain, and when the ration contained 64-percent forage, a pound of forage replaced only 0.1 pound of grain.

Capital and Labor Requirements of Feed-Utilization Systems

The substitution relationships between forage and grain in the rotation and in the livestock ration may indicate that it would pay to increase production and utilization of forage. But some farmers lack sufficient capital or borrowing power to expand their investments in roughage-consuming livestock. In allocating their limited capital among alternative enterprises, these farmers are concerned with getting a high return from a small investment. If they invest their capital in the livestock enterprises that yield the highest returns per dollar of investment they may not have the kind and number of livestock needed to consume a large quantity of forage. In such cases it will not pay to expand forage acreage beyond the extent to which it becomes competitive with grain in the crop rotation.

The analysis shows that, from 1917 to 1948, hogs consistently yielded higher returns per dollar of investment than other classes of livestock that have greater capacity to consume forage. For example, on the basis of 1944–48 price relationships, hogs fed on a relatively high-forage ration returned an annual net income of $66 per $100 invested. In contrast, a similar investment in good dairy cows fed a high-forage ration returned only $7 net income annually. On the basis of 1944–48 prices, an initial investment of $17,868 would be required to establish a hog enterprise that would utilize 100 tons of forage, whereas an investment of only $6,642 would be required to establish a dairy enterprise to consume that quantity of forage.

The amount of labor required for alternative feed-utilization systems and its distribution throughout the year must also be considered in selecting the feed-utilization system for an individual farm. In general, feed combinations that contain a high proportion of forage take somewhat more time to produce a given output of livestock than do high-grain rations. In some cases this results in greater labor requirements per unit of livestock product produced. However, labor

requirements are not consistently higher for the high-forage rations than for the high-grain rations. Differences in labor requirements for various rations fed a particular kind of livestock are small in comparison with differences among kinds of livestock.

Risk and Uncertainty

The risk and uncertainty associated with several utilization systems were measured in terms of the variability of returns from each during the 32 years from 1917 to 1948. The data show that variability of income differs very little for different grain-forage combinations fed a particular kind of livestock. Differences in variability of income associated with different kinds of livestock, however, were important. Income from feeder cattle fluctuated a great deal more than returns from hogs or dairy cattle. Dairy cows showed the least variability in returns. In judging which of the feeding systems is most desirable, a farmer may balance the prospective average returns over time against the variability of these returns from year to year in light of his own ability and willingness to bear risks.

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